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Silicone elastomers with high-permittivity ionic liquids loading

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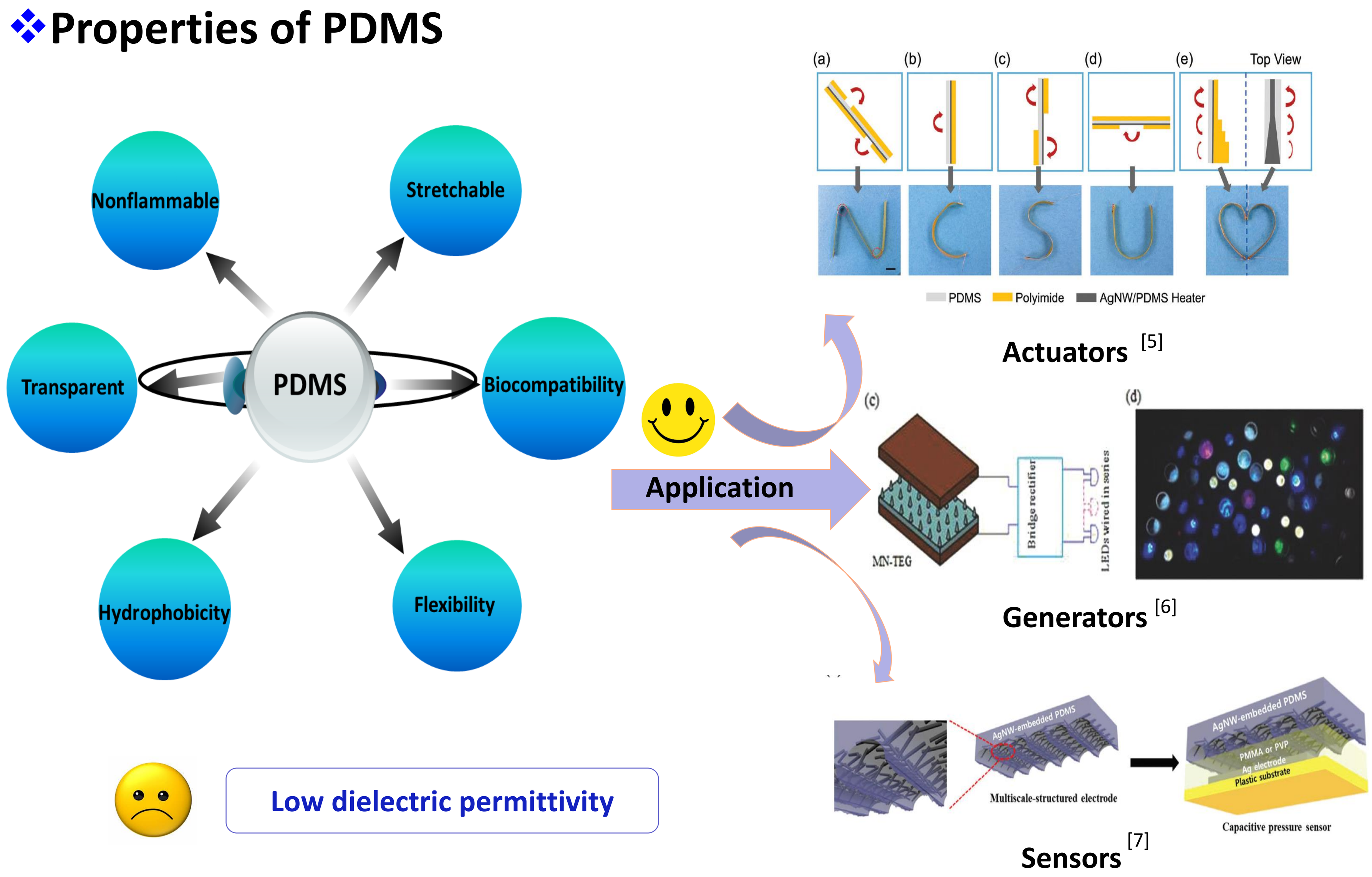
Abstract

Dielectric elastomers transducers (DETs) represent a promising transducer technology, due to their excellent ability to undergo large and reversible deformations under an applied electric field.[1] The most obvious challenge facing current DEs is the high driving voltages necessary to drive them,[2] and so an effective way to overcome this shortcoming is to increase the dielectric permittivity of the applied elastomers.[3] Ionic liquids (ILs), which have gained significant attention in recent years, have high permittivity but also high conductivity. It is therefore interesting to blend ILs into elastomers to increase their dielectric permittivity while focusing on maintaining the non-conductive nature of the elastomers.[4] Herein, high-permittivity silicone elastomers were prepared from blending in ILs. The influence of the structure and the content of ILs on the material properties was discussed, and important properties for material applications as DETs, such as dielectric permittivity, gel fraction and mechanical properties, were also investigated. It was found that 1-butyl-3-methylimidazolium hexafluoroantimonate ($BmimSbF_6$) is the most suitable IL for the given elastomer system. The dielectric permittivity of the elastomers increased with the increasing content of $BmimSbF_6$. The Young's modulus decreased in line with the increasing content of $BmimSbF_6$, as expected. A simple figure of merit (F^*_{om}) for actuators was used and the resulting F^*_{om} of elastomer with 90 phr IL loading is 10.40 thereby indicating that the material has a great advantage when used in actuators.

Background

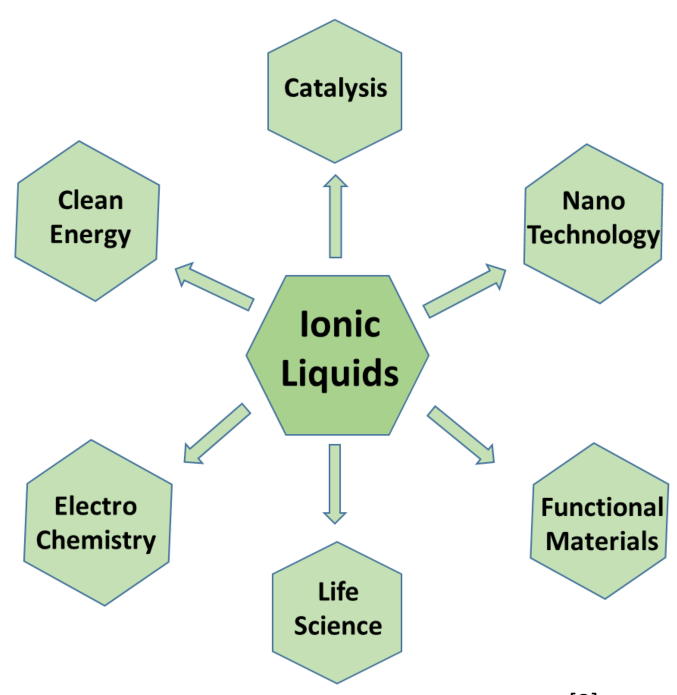
❖Properties of PDMS



❖Introduction of ionic liquids (ILs)

Properties of ILs

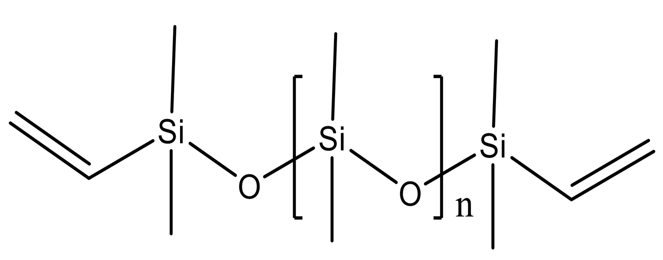
- ❖High chemical stability and thermal stability
- ❖Liquid at room temperature
- ❖Low vapor pressure
- ❖High dielectric permittivity
- ❖Tunable structure and properties
- ❖Wide electrochemical window
- ❖High electrical conductivity



Application of ionic liquids [8]

Experimental

❖Materials



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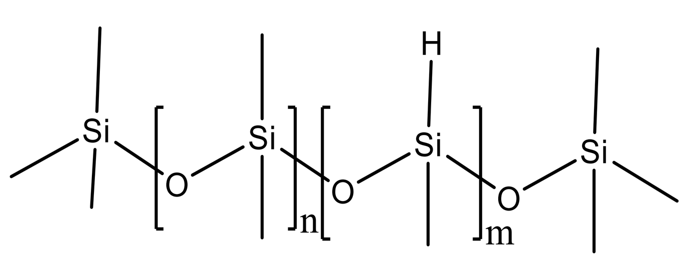
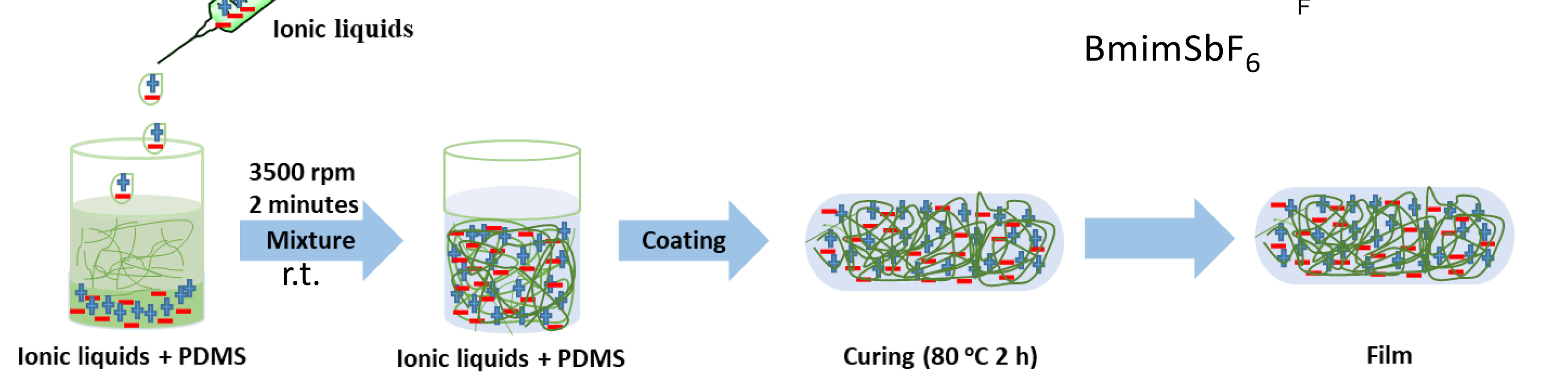
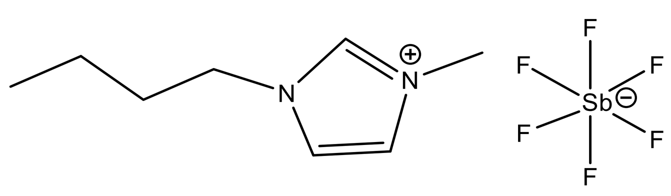


HMS301

❖Method

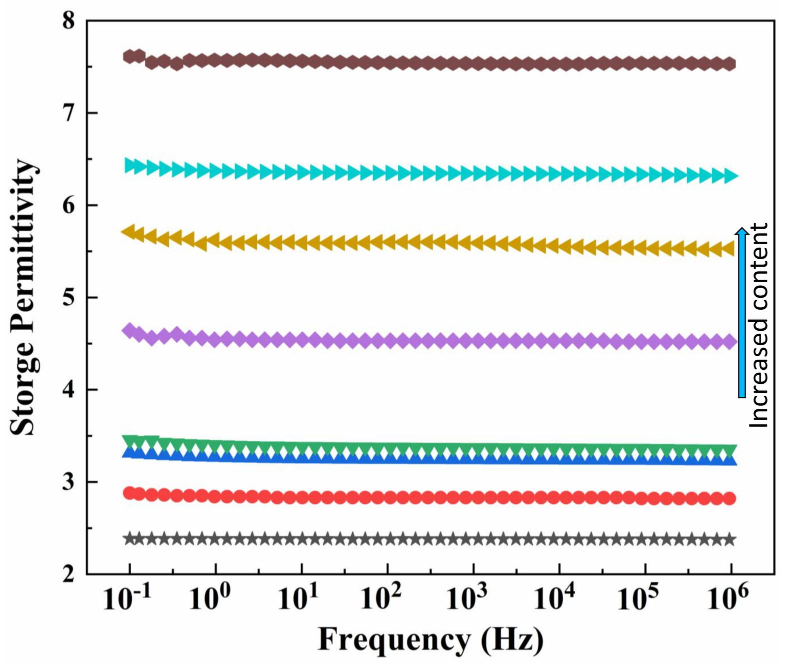




$BmimSbF_6$

Results and discussion

❖ Effect of $BmimSbF_6$ content on dielectric properties



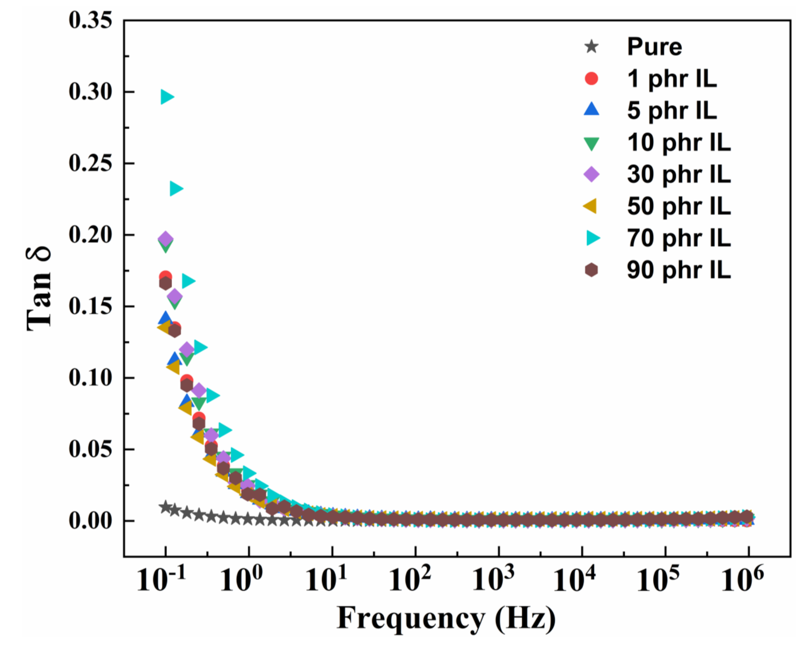
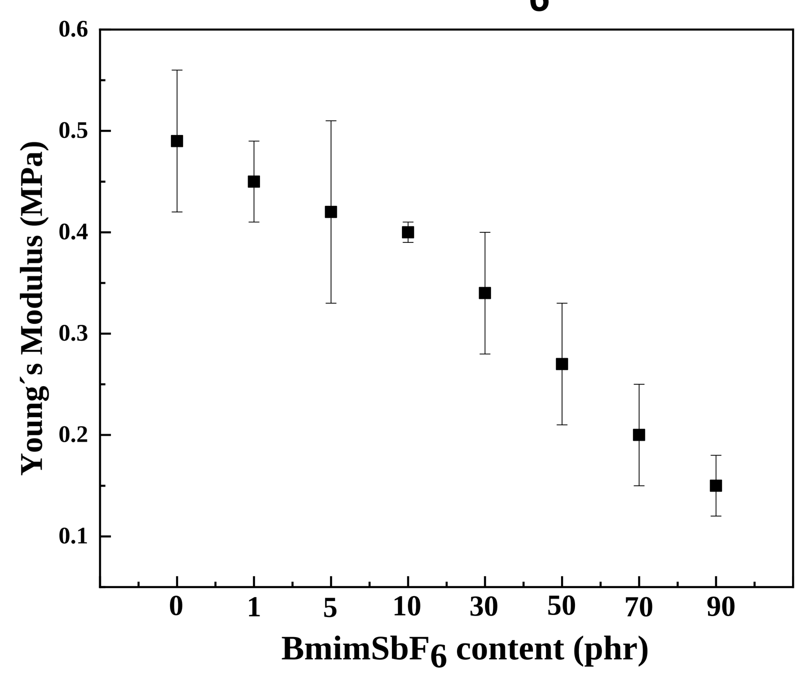


Fig. 1 Storage permittivity (left) and tan(δ) (right)of films with different content of $BmimSbF_6$ at room temperature.

❖ Effect of $BmimSbF_6$ content on mechanical properties



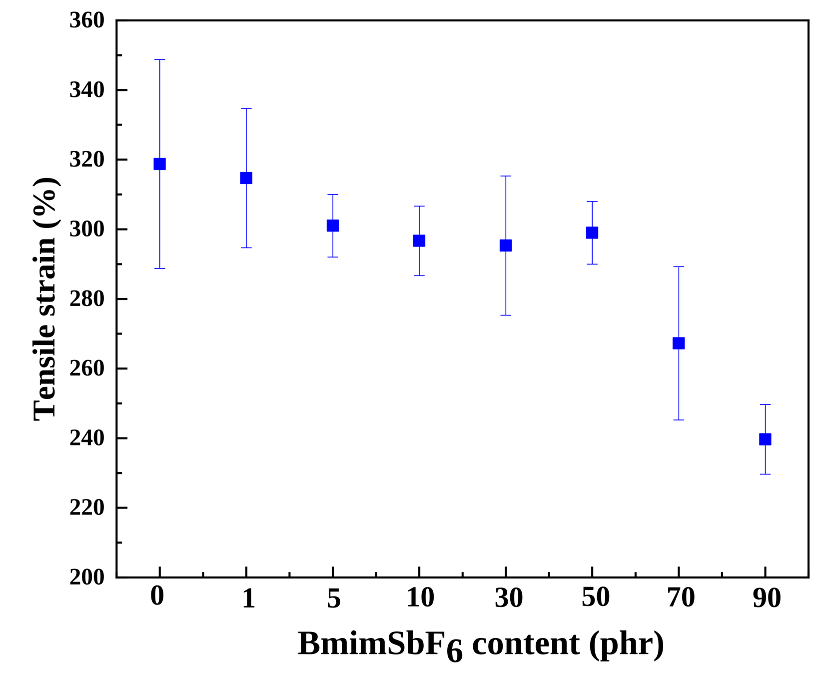
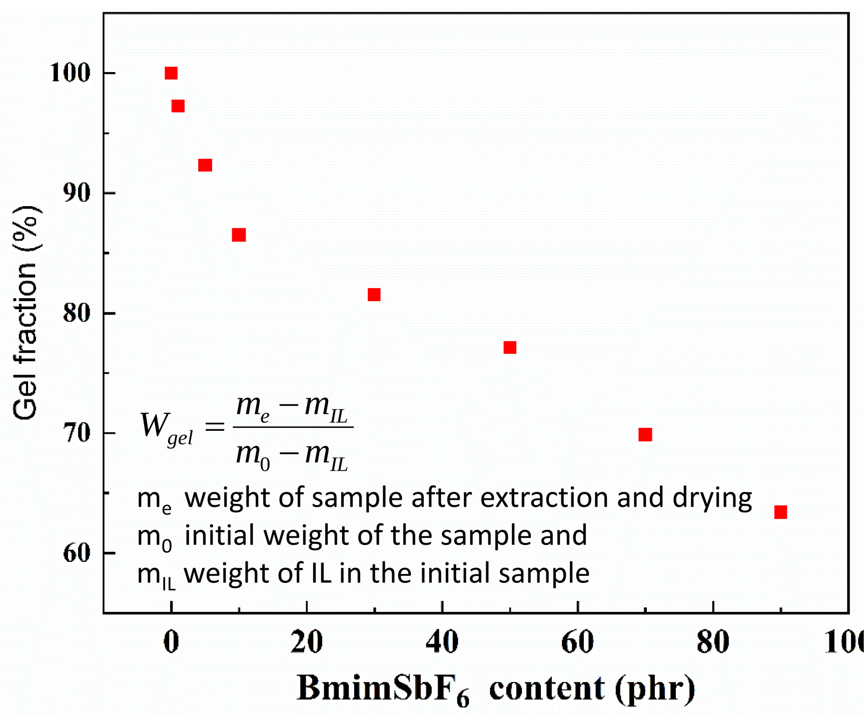


Fig. 2 Young's modulus (left) and tensile strains (right)of films with different content of $BmimSbF_6$ at room temperature.



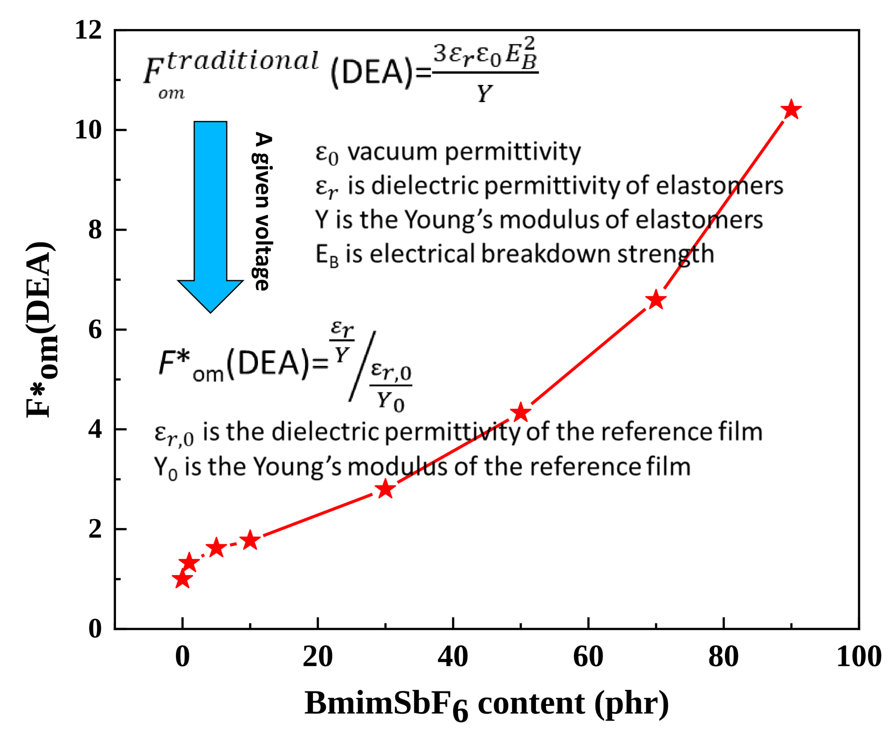
$$W_{gel} = \frac{m_e - m_{IL}}{m_0 - m_{IL}}$$

m_e weight of sample after extraction and drying
m_0 initial weight of the sample and
m_{IL} weight of IL in the initial sample

Fig. 3 Gel fractions of films with different content of $BmimSbF_6$.

❖ Effect of $BmimSbF_6$ content on F^*_{om}

F_{om} is a universal parameter to evaluate the DET performance at a constant potential.[2]



$$F^{traditional}_{om}(\text{DEA}) = \frac{3\varepsilon_r \varepsilon_0 E_B^2}{Y}$$

ε_0 vacuum permittivity
ε_r is dielectric permittivity of elastomers
Y is the Young's modulus of elastomers
E_B is electrical breakdown strength

$$F^*_{om}(\text{DEA}) = \frac{\varepsilon_r}{Y} \Big/ \frac{\varepsilon_{r,0}}{Y_0}$$

$\varepsilon_{r,0}$ is the dielectric permittivity of the reference film
Y_0 is the Young's modulus of the reference film

Fig. 4 F^*_{om} of films with different content of $BmimSbF_6$.

Conclusion

- ❖ Very few ILs are compatible with Pt curing chemistries; $BmimSbF_6$ is one of those.
- ❖ The storage permittivity of film increased in line with increasing $BmimSbF_6$ content.
- ❖ The elastomers with IL loaded became increasingly softer in line with an increasing content of $BmimSbF_6$.
- ❖ The figure of merit (F^*_{om}) increased with increasing $BmimSbF_6$ content.

Acknowledgments

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